Use of Opaque-2 Corn Flour with White Wheat Flour

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Replacing wheat flour with up to 35% opaque corn flour increased the protein efficiency ratio (PER) by up to 0.34; replacing the wheat flour with 30% wheat protein concentrate (WPC) or 15% corn flour plus 20% WPC increased the PER by 0.39. Increased protein quality was accompanied by substantial impairment of breadmaking quality when corn was used at levels exceeding 20%.

Compared to white wheat flour and normal corn, opaque-2 corn supplies not only adequate amounts of most amino acids but it also contains about twice as much lysine, an amino acid most limiting in wheat protein (Mertz *et al.*, 1964; Pick and Meade, 1971; Waggle *et al.*, 1967). Since fortification of wheat flour with pure lysine is not always possible, use of high-lysine corn as such or in combination with other lysine-rich sources to achieve this, in order to alleviate protein deficiency worldwide, may hold a promise. Present studies report the effect of supplementing white wheat flour with opaque-2 corn flour (whole kernel flour) as such and in combination with wheat protein concentrate (WPC, a high-lysine high-protein low-fiber flour prepared from millfractions) on its protein quality and baking characteristics.

EXPERIMENTAL SECTION

Preparation of Breads and Scoring. White flour from hard red spring wheat was replaced to the extent of 0, 20, 25, 30, 35, and 40% with opaque corn flour in experiment A and with a combination of corn flour (15%) and WPC (20%) and WPC (30%) alone in experiment B. Pound loaves were made from substituted flour by a straight dough method (Kulp, 1970) based on the formula (%): flour, 100; yeast, 2.5; yeast food, 0.5; salt, 2.0; lard, 3.0; sugar, 6.0; and water as in Table I. Same flour, from different bags each time, was used. Ingredients were mixed in a Hobart model AI-20 mixer using bowl and hook. Baking was done at 400°F for 25 min (14 min for rolls). Dough water absorption and dough mixing time (time required to reach desired consistency) were measured during mixing but were based on preliminary test mixes. Loaf volume was measured by the rapeseed displacement method. Breads were scored for acceptability by the baking technologist (Table I) based on the following characteristics: texture, grain, break and shred, and crust and crumb color. A roll-type product was also baked from one of the bread doughs (C-35).

Diets. The experimental diets to evaluate protein quality of breads were prepared by air-drying the breads and grinding them to fine crumbs. Each diet was formulated to contain 10% protein where possible (Table II). In addition to the protein source, all diets also contained (%): corn oil, 3; sodium chloride, 1; salt 446 (General Biochemicals), 3; vitamin diet fortification mixture (Nutritional Biochemicals), 2; and dextrin to make 100. Only three of the six types of breads baked in experiment A and all three baked in experiment B were tested.

Protein Efficiency Ratio (PER) Determination. The PER of each bread was determined separately using individually housed weanling male rats (Sprague-Dawley), six per diet, averaging about 55 g initially. Diets, premixed with water to form a slurry to minimize wastage, were fed *ad libitum* for 4 weeks. The weekly gain in weight and diet consumption was recorded. A casein diet served as the reference control in each experiment. The PER was calculated from increase in weight in 4 weeks (g)/total protein (g) consumed.

Analytical. The samples of wheat flour, WPC, corn flour, and casein were analyzed for protein (N × 5.7 for wheat and N × 6.25 for corn and casein) contents according to the method of the American Association of Cereal Chemists (1962). Lysine was determined by ion exchange chromatography as described earlier (Ranhotra *et al.*, 1971a). Table III lists results of these analyses and gives particle size of the flours used.

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RESULTS AND DISCUSSION

Rheological and Baking Characteristics. Increasingly substituting wheat flour with corn flour did not affect dough water absorption, but the stability of the dough was increasingly reduced as dough mixing times indicate (Table I). Loaf volume and other bread characteristics examined were also progressively adversely affected. Corn at levels higher than 25% affected crumb texture the most, and the overall acceptability of the bread containing over 20% corn was greatly reduced. Dough mixing time, loaf volume, and other bread characteristics were equally adversely affected in breads baked with flour substituted with WPC plus corn and just WPC alone (experiment B). Loaf volume did not differ much, however, although other bread characteristics showed appreciable differences. Simultaneous substitution with corn plus WPC imparted to the loaf a golden-yellowish more acceptable color than substitution with WPC alone.

Protein Quality (PER). In experiment A, rats fed all-wheat bread showed an appreciable increase in their food intakes and weight gains with part substitution of wheat flour with corn. Between the three corn-substituted diets tested (C-25, C-35, C-35R) no appreciable differences were, however, observed, apparently due to unequal protein content of these diets although PER improved progressively. Corrected PER increased by 0.24 and 0.34 with 25 and 35% substitution with corn, respectively, apparently due to an increase in lysine content (Table III) but possibly also due to an overall improvement in amino acid balance (Dutra De Oliveira and Pereira Da Silva, 1971). While Reddy (1971) recently reported no improvement in nitrogen retention of moderately undernourished children fed lysine-fortified whole wheat, most other workers (Graham *et al.*, 1969; Pereira *et al.*, 1969) have reported to the contrary. Under conditions of severe protein malnutrition and desired rapid recovery and where lysine-poor white wheat flour is used, a definite improvement to lysine fortification of wheat flour has repeatedly

Table I. Rheological and Baking Qualities

	Experiment A							Experiment B		
	Bread						Roll	Bread		
	C-0	C-20	C-25	C-30	C-35	C-40	C-35R	W-0	W-20	W-30
White wheat flour, %	100	80	75	70	65	60	65	100	65	70
Opaque corn flour, %	0	20	25	30	35	40	35	0	15	0
Wheat protein concentrate, %	0	0	0	0	0	0	0	0	20	30
Dough water absorption, ml/100 g sample	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.9	66.9	66.9
Dough mixing time, min	24	9	7	7	6	6	10	24	6	6
Loaf volume, ml	2500	2425	2150	2000	1825	1650		2675	1925	2000
General bread characteristics, score[a]	3.8	3.0	2.7	2.3	2.3	2.3		4.0	2.5	3.2

[a] Excellent, 5; very good, 4; good, 3; fair, 2; and poor, 1.

Table II. Diet Composition and Protein Efficiency Ratios (PER)

	Experiment A					Experiment B			
		Bread			Roll		Bread		
	Casein	C-0	C-25	C-35	C-35R	Casein	W-0	W-20	W-30
Diets									
Protein source, g	11.51	87.71	100.00	100.00	100.00	11.51	84.38	80.77	76.04
Others,[a] g	88.49	12.29	9.0	9.0	9.0	88.49	15.62	19.23	23.96
Protein, %	10.00	10.00	10.07	9.65	9.45	10.10	10.10	10.07	10.05
Rat performance									
Food intake, g/day	15.47[b] ±1.95	9.68 ±0.63	11.85 ±1.16	11.98 ±0.78	11.97 ±0.82	16.23 ±1.07	9.77 ±1.19	12.92 ±1.16	12.82 ±0.29
Weight gain, g/day	5.20 ±0.81	1.31 ±0.10	2.00 ±0.25	2.10 ±0.15	2.15 ±0.15	5.28 ±0.50	1.40 ±0.34	2.50 ±0.35	2.46 ±0.22
PER as measured	3.35 ±0.16	1.35 ±0.08	1.68 ±0.09	1.82 ±0.10	1.90 ±0.13	3.25 ±0.13	1.41 ±0.20	1.92 ±0.13	1.92 ±0.15
PER as corrected to 2.5 for casein	2.50 ±0.11	1.01 ±0.11	1.25 ±0.06	1.35 ±0.08	1.42 ±0.10	2.50 ±0.10	1.09 ±0.16	1.48 ±0.10	1.48 ±0.11

[a] See text. [b] Mean ± standard deviation.

Table III. Protein and Lysine Contents

	Approx particle size, U.S. sieve, mesh	Protein, g/100 g	Lysine, g/100 g
White wheat flour	140	12.20	0.247
Opaque-2 corn flour	80	10.35	0.435
Wheat protein concentrate	100	17.40	0.709

been shown. Rolls in present studies were baked for a shorter duration of time than breads. Since destruction of lysine was probably less because of this (Ranhotra *et al.*, 1971b), a somewhat better PER was obtained. PER of opaque corn was not tested but Bressani *et al.* (1969) have reported a value of 2.79 compared to 2.88 for casein. Where wheat flour was substituted with a combination of WPC plus corn and just WPC (experiment B), corrected PER increased by 0.39 in each case, suggesting that the "available" lysine from both types of breads was about equal. The contents of lysine in corn and in WPC (Table III) seem to support this.

Summarizing, the results suggest that with some sacrifice of normally acceptable bread quality, protein quality of white bread can be greatly improved by fortification of white wheat flour with opaque corn at a level of about 25%.

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LITERATURE CITED

American Association of Cereal Chemists, AACC Approved Methods, 7th ed., The Association, St. Paul, Minn., 1962.
Bressani, R., Elias, L. G., Gomes-Brenes, R. A., *J. Nutr.* **97**, 173 (1969).
Dutra De Oliveira, J. E., Pereira Da Silva, M. L., *J. Food Sci.* **36**, 370 (1971).
Graham, G. G., Placko, R. P., Acevedo, G., Morales, E., Cordano, A., *Amer. J. Clin. Nutr.* **24**, 1459 (1969).
Kulp, K., in "Report of Sixth National Conference on Wheat Utilization Research," Agricultural Research Service, USDA, ARS 74-54, 1970.
Mertz, E. T., Bates, L. S., Nelson, O. E., *Science* **145**, 279 (1964).
Pereira, S. M., Begum, A., Gesudian, G., Sundararaj, R., *Amer. J. Clin. Nutr.* **22**, 606 (1969).
Pick, R. T., Meade, R. J., *J. Nutr.* **101**, 1241 (1971).
Ranhotra, G. S., Hepburn, F. N., Bradley, W. B., *Cereal Chem.* **48**, 9 (1971a).
Ranhotra, G. S., Hepburn, F. N., Bradley, W. B., *Cereal Chem.* **48**, 699 (1971b).
Reddy, V., *Amer. J. Clin. Nutr.* **24**, 1246 (1971).
Waggle, D. H., Lambert, M. A., Miller, G. D., Farrell, E. P., Deyoe, C. W., *Cereal Chem.* **44**, 48 (1967).

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